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Evaluation of Two Simple Functional Tests to Predict Attrition from Combat Service in Female Light Infantry Soldiers

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Statistical Analysis C
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Background: Worldwide, there is a high attrition rate, or dropout rate, from combat in trained soldiers, mainly due to musculoskeletal injuries. This study aimed to determine whether the use of an upper limb stability test, the Upper Quarter Y-Balance Test (UQYBT), and a modified version of the Ranger Test (MRT) that included a lower limb step-up endurance test, could predict attrition from combat service in female infantry soldiers.

Material/Methods: In 2015, a group of 167 newly recruited female light infantry soldiers were evaluated using the UQYBT and the MRT. Data regarding attrition from combat service were collected in 2017, 18 months after screening. Multiple logistic regression analysis was used to determine the predictive effect of body mass index (BMI), UQYBT, and MRT scores on attrition from combat service.

Results: Fifty-three female soldiers (31.7%) dropped out of combat service during the 18 months following recruitment. The MRT score was a significant predictor of attrition, with each additional incremental increase in the MRT score reducing the attrition rate by 6.8% (OR=0.934; 95% CI, 0.895–0.975). A cutoff MRT score of 12 increments predicted attrition with 73.7% sensitivity and 50.9% specificity. The UQYBT scores and BMI were not significant predictors.

Conclusions: The use of the MRT during military training, was a predictive screening method to predict attrition from combat service in Israeli female infantry soldiers. Further studies are required to evaluate the use of the MRT in other groups of women in the military.

MeSH Keywords: **Cumulative Trauma Disorders • Mass Screening • Military Science**

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Background

Military organizations around the world have to manage the consequences of recruits who, for various reasons, do not progress beyond basic training. High attrition rates, or high dropout rates, is problematic, because it disrupts military readiness, and increases financial costs with loss of resources due to the unfulfilled investment made in the process of military training [1,2]. Attrition can be due to a physical or medical condition [3], inability to meet performance criteria, or behavioral issues [1,4]. Orthopedic and mental conditions are the most common reasons for early attrition in the military [3]. Older age, smoking habits, marital status, physical fitness, and previous injury are among the common risk factors for early attrition [5–10].

Recently, the recruitment of female soldiers into combat units has increased dramatically, particularly in the United States (US) and Australia where all military roles are open to women [11,12]. In the Israeli Defense Force, 30% of military roles were open to women in 1976, rising to 78% in 1997 [13]. Controversy still exists regarding the ability of women to serve in combat units, due to the physical differences between women and men [14]. Also, higher attrition rates have been reported among female military service personnel in several studies [8,15–17]. Knapik et al. reported an 11.8% discharge rate for women, compared with 6.6% of men during similar US Army basic combat training [17]. In a study of attrition rates among US Marine Corps active duty enlistees during the first 19 months of their service, the attrition rate was significantly higher for female recruits (18.2%) than for male recruits (11.9%) [16]. Another study on the Marine Corps reported a cumulative attrition rate of 17.1% among female recruits [8]. However, in contrast to these studies, Finestone et al. who studied a mixed light infantry unit found similar attrition rates at 18 and 36 months of service [4]. However, the incidence of musculoskeletal injuries was significantly higher among female light infantry soldiers compared with male light infantry soldiers [4].

Different branches of the military have used several methods of medical and psychological screening with the goal of identifying recruits who are unsuitable for deployment [18,19].

While some screening procedures can be easily applied, others often require sophisticated equipment, highly-trained examiners, and large amounts of time. For example, measurement of physical fitness using maximal oxygen intake (VO_2max), which was reported to predict attrition and injuries, can be determined by a simple two-mile or three-mile run time [6,10]. In contrast to simpler evaluation methods, a computerized analysis of gait was used by Springer et al. to identify certain specific gait parameters that predicted lower limb injuries among infantry soldiers [20]. Tiggelen et al. reported that measurement of isokinetic strength could distinguish between recruits who would or would not develop anterior knee pain [21].

Some of the published screening methods to evaluate the physical suitability of military recruits are not feasible for use in screening large populations, and more effective screening tests that can be used on large groups are needed [22]. In response to this need, the Israeli Defense Force Medical Corps Warrior Health Center (WHC) implemented a simple pilot method to assess new female recruits planning to serve in combat units. The purpose of this screening procedure was to identify individuals at high-risk for exertional musculoskeletal injuries and for premature discharge from military combat service. This screening procedure was based on two functional tests, the Upper Quarter Y-Balance Test (UQYBT) [23], and a modified version of the Ranger Test (MRT) [24]. The UQYBT is a kinematic assessment of upper quadrant mobility, stability, and strength, that has been validated to be predictive for training-related injuries [25]. Cosio-Lima et al. reported that a low composite UQYBT score was a risk factor for general injuries in a male population of coast guard trainees [25]. The authors concluded that low composite scores might be related to lack of flexibility or insufficient muscular strength with which to stabilize their body while moving [25]. The Ranger Physical Fitness Test, which is different from the Army Physical Fitness Test, is a sub-maximal muscle endurance step-test that has been shown to be useful in predicting discharge from basic training due to lower limb injuries in male soldiers in Sweden [24].

The two tests, the UQYBT and the MRT, were chosen because they are inexpensive and straightforward to conduct, they examine both the upper and lower extremities, and they reflect the challenging demands of combat duty. Previous studies that have used testing of the upper and lower extremities found that the combination of the step-test without additional weight loading and a push-up test predicted attrition in a mixed population of 7,612 male and female soldiers [26]. Also, while psychological aspects are not measured directly, it is thought that success in challenging physical tasks may be an indication of motivation and resilience [26–28].

The aim of this study was to determine whether the use of an upper limb stability test, the UQYBT, and the MRT that included a lower limb step-up endurance test could predict attrition from combat service in female infantry soldiers in Israel.

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Material and Methods

Study design

A retrospective cohort study included female light infantry soldiers recruited to the Israeli Defense Force who were screened at the Israeli Defense Force Medical Corps Warrior Health Center (WHC) during 2015. The medical records of female soldiers who completed the screening process during their first two weeks of military service were included and analyzed in 2017. The two screening tests used were the Upper Quarter Y-Balance Test (UQYBT), and a modified version of the Ranger Test (MRT). The study was approved by the Israeli Defense Force Medical Corps Ethics Review Board (approval number IDF-1569/70-2015).

The Upper Quarter Y-Balance Test (UQYBT)

The UQYBT was performed, as previously described, using a Y-Balance Test Kit, the Move2Perform movement measurement and analysis tool (Move2Perform, Evansville, IN, USA) [23,29,30]. The kit consisted of a stance platform to which three pieces of polyvinyl chloride pipe were attached in the medial, inferolateral, and superolateral reach directions. The medial pipe was positioned 135° from the lateral pipes, and there was an angle of 90° between the inferior and superior pipes. Each pipe was marked in 0.5 cm increments for movement measurement. A reach indicator on the pipes was used to measure how far the subject could reach. The reach indicator remained in place over a tape measure during the performance of the test, to improve the accuracy of measurement of the reach distance (Figure 1).

While maintaining a push-up position with the feet no further apart than the pelvic width, the subject performed three maximal reaches in three directions for each hand. The subject repeated the test if they lost their balance or if a foot lost contact with the ground while performing the test.

The average of three tests in each direction was calculated, and the average of the scores for three directions was calculated as a composite score for each hand. A total composite score was calculated based on the average of the right and left composite scores. The total composite score was calculated as a percentage of the subject's height. Using the subject's height instead of limb length, as previously reported, was unlikely to alter the results, as the upper limb length and height are strongly correlated [31]. This method was chosen as height was always measured, which made the test more time efficient (Figure 1).

The modified Ranger Test (MRT)

The modified Ranger Test (MRT) is regarded as a relevant test to use for military recruits as it reflects routine daily physical activities, including load bearing and walking on rough terrain. Larsson and Harms-Ringdahl introduced the Ranger Test, a loaded lower limb step-up endurance test [24]. The test's results are not adjusted for height, as the physical demands of soldiers are similar regardless of their stature.

Figure 1. The Upper Quadrant Y-Balance Test (UQYBT).

During the MRT, subjects wore an 8 kg load, and performed the maximum number of step-ups on a 0.4 m step, while maintaining a pace of 25 steps per minute. Before the test, the subject performed several weight-free trials, to choose her preferred leg. Then, while keeping the tested leg on the step during the entire test, the subject stepped up and down on the step. The subjects were instructed to maintain a straight posture. A digital metronome marked the pace. The test was terminated when the subject could no longer maintain the pace or straighten her body. Participants received verbal information regarding their performance, their pace or body posture before the test was terminated. The MRT score was determined by the number of repetitions performed before the test was terminated.

Attrition rates of female light infantry soldiers at 18 months

Data regarding attrition rates were collected 18 months after screening. At this point, all female light infantry soldiers were half-way through their mandatory military service in the Israeli Defense Force and were past the basic training phase. Medical files were reviewed to identify three main factors, relocation of the soldiers to a non-combat unit, a job description that indicated a non-combat position in a combat unit, or discharge from military service.

Statistical analysis

Descriptive data were described numerically for the basic characteristics of age, height, weight, and body mass index (BMI), as well as MRT and UQYBT scores. The Student's t-test was performed to determine the differences between the baseline characteristics of soldiers who left combat service and those

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Table 1. Baseline characteristics of participants (mean ± standard deviation) and categories according to the distribution of body mass index (BMI) (percentage).

Characteristic	All (N=167)		Attrited (N=53)		Not attrited (N=114)		p-Value
Age (years)	18.6	(0.5)	18.6	(0.51)	18.6	(0.46)	0.96
Height (meters)	1.61	(0.06)	1.61	(0.06)	1.61	(0.06)	0.9
Weight (kg)	61.8	(10.2)	63.1	(11.0)	61.2	(9.8)	0.26
BMI	23.8	(3.8)	24.3	(4.1)	23.6	(3.6)	0.28
Under-weight	2	(1.2%)	1	(1.9%)	1	(0.9%)	
Normal-weight	113	(67.7%)	34	(64.2%)	79	(69.3%)	
Over-weight	40	(24%)	13	(24.5%)	27	(23.7%)	
Obese	12	(7.2%)	5	(9.4%)	7	(6.1%)	

Table 2. Summary of the results of functional testing.

Test	All (N=167)	Attrited (N=53)	Not attrited (N=114)	p-Value	95% CI of mean difference
UQYBT* mean (SD)	36.9 (5.9)	36.4 (6.6)	37.2 (5.6)	0.391	−1.1–2.81
mRT** mean (SD)	18.8 (11.7)	14.6 (8.3)	20.8 (12.6)	0.001	2.46–9.94

* UQYBT – Upper Quadrant Y-Balance Test. Composite score is calculated as the average of all 18 trials (three trials per direction, three directions for each side) divided by the subject's height; ** mRT – modified Rangers Test, repetitions completed.

who did not. Test-retest reliability of the UQYBT scores was assessed using interclass correlation (ICC) to verify the use of the UQYBT composite score. Pearson's correlation analysis and coefficient (r) were used to assess relationship between the UQYBT scores of the different sides and directions, as well as to assess the relationship between the UQYBT and MRT scores and the height and weight of each study participant.

Multiple logistic regression analysis was performed to measure the predictive ability of the BMI, MRT, and UQYBT scores on attrition from combat service, including Nagelkerke's R^2 and the chi-squared (χ^2) test. Receiver operating characteristic (ROC) analysis was used to examine the area under the curve (AUC), the cutoff value of the strongest predictor, and the test sensitivity and specificity. A p-value <0.05 was considered to be statistically significant. SPSS version 23.0 software (IBM Corp., Armonk, NY, USA) was used for statistical analysis.

Results

The medical records of 167 female light infantry soldiers were included in the final analysis. At follow-up, 53 subjects (31.7%) were not serving as combat soldiers. Demographic and anthropometric characteristics, including the body mass index [32], of the participants are presented in Table 1. There was no difference in baseline characteristics of age, height, weight, and BMI, between the soldiers who discontinued combat service and those who did not (Table 1).

The Upper Quarter Y-Balance Test (UQYBT), and modified version of the Ranger Test (MRT) scores are presented in Table 2. The average UQYBT scores were weakly correlated with both height (r=0.1, p=0.19 for the right side; r=0.11, p=0.15 for the left side) and weight (r=–0.25, p=0.001 for the right side; r=–0.26, p=0.001 for the left side). The MRT scores showed a weak correlation with height (r=0.2, p=0.01) and weight (r=–0.175, p=0.023) of the study participants.

The test-retest reliability of the UQYBT was calculated and the results are presented in Table 3. The mean UQYBT scores for each direction and side were significantly correlated with the total score for that side, as presented in Table 4. Also, composite scores of the left and right hands were significantly correlated (r=0.898, p<0.001). Therefore, the total composite score was used in the regression model, to avoid multiple colinearity (Tables 3, 4).

Multiple logistic regression analysis was performed to determine the relative predictive value of the three variables of BMI,

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Table 3. The specificity and sensitivity of the Upper Quadrant Y-Balance Test (UQYBT).

Side and direction	ICC(2) value	95% CI
Left medial	0.829	0.785–0.866
Left inferolateral	0.817	0.771–0.856
Left superolateral	0.837	0.795–0.872
Right medial	0.889	0.859–0.914
Right inferolateral	0.802	0.754–0.844
Right superolateral	0.85	0.811–0.883

Table 4. Pearson's correlation between the Upper Quadrant Y-Balance Test (UQYBT) scores of each side.

Right side	Right composite average		Left side	Left composite average	
	Pearson r	p-Value		Pearson r	p-Value
Right medial	0.895	<0.001	Left medial	0.878	<0.001
Right inferolateral	0.865	<0.001	Left inferolateral	0.869	<0.001
Right superolateral	0.899	<0.001	Left superolateral	0.894	<0.001

MRT scores, and UQYBT scores on the likelihood of attrition from combat service. Statistical analysis showed only one significant variable, which was the MRT scores (χ^2=13.35, df=3, Nagelkerke R^2=10.8%, p=0.004). Each increment in the MRT score decreased the chance of attrition by 6.8% (OR=0.934; 95% CI, 0.895–0.975). Analysis of the receiver operating characteristic (ROC) curve was used to determine the optimal MRT score cutoff value, which was 12 repetitions, and the area under the curve (AUC) was 0.664. The MRT had a sensitivity of 73.7% and specificity of 50.9% as a predictor of attrition from combat, following infantry training, in female Israeli soldiers.

Discussion

For women who join the military and who are about to undergo military training, the need for screening new applicants to identify those who are at greatest risk of dropping out of combat service is now well recognized, and the cost and resource implications of attrition rates are regarded as important [8,17]. This study aimed to determine whether the use of an upper limb stability test, the Upper Quarter Y-Balance Test (UQYBT), and a modified version of the Ranger Test (MRT) that included a lower limb step-up endurance test, could predict attrition from combat service in female light infantry soldiers in Israel. The results showed that the MRT score at recruitment could identify female soldiers who might not progress past basic training. However, the UQYBT and body mass index (BMI) were not found to be significant predictors of attrition from combat service.

Worldwide, attrition from combat service has been shown to be mainly due to musculoskeletal injury or underlying medical conditions that affect physical activity [3]. Most medical reasons for attrition are due to lower limb musculoskeletal overuse injuries, including stress fractures and anterior knee pain [3,5,7]. Injuries to the lower limb can be assumed to be more restrictive and disabling than other injuries and to be associated with higher rates of attrition from combat service in the military. Therefore, it is not surprising that a lower limb test was found to be useful in identifying female members of the light infantry who were at risk of attrition from combat service.

However, upper limb injuries are also common during military training. In a previously published study that investigated the incidence of injury-related musculoskeletal conditions in the US military services, upper extremity injuries, including recurrent shoulder dislocations and rotator cuff tendinitis, comprised 14% of the total injuries [33]. As these injuries might affect attrition rates, an upper limb functional test might be useful during the screening of applicants for military service. However, the findings of the present study showed that the UQYBT, an upper limb functional test, was not found to be a significant predictor, which might be related to the characteristics of the study cohort. It is possible that a larger study sample size would have demonstrated significant results for the use of the UQYBT. Also, a group of female light infantry soldiers was studied. The role of light infantry soldiers, in terms of physical demands, is less than that of regular infantry soldiers, which may reduce the risk of upper limb injuries during combat service [4].

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The two functional tests used in this protocol, the MRT and UQYBT, were intended to represent some of the components of military practice and tasks. The MRT reflects marching while carrying heavy loads and the UQYBT assesses muscular activity required for reaching and crawling. The physical abilities measured by these two tests are different. The MRT is a measure of endurance, while the UQYBT measures strength and stability. Niebuhr et al. found that the results from a combination of two endurance tests, a step-test for evaluation of the function of the lower limb and a push-up test for the assessment of the upper limb, predicted attrition better than each test alone [26]. Further large-scale prospective studies may answer the question regarding the value of the results of upper limb functional tests that assess endurance and the prediction of the risk of attrition in military service.

In the present study, the MRT was found to be a significant predictor of attrition, but with a sensitivity of 73.7% and a specificity of 50.9%. However, these findings should encourage further studies on the combinations of tests that enhance the predictive ability of the MRT as a method of screening potential military recruits. For example, assessment of the predictive value of a screening procedure that assesses both aerobic capacity and sub-maximal endurance might be considered.

Both high and low BMI values are considered to be risk factors for injuries caused by overuse and exertion, especially among women [7,34–36]. The suggested etiology of these injuries include the physical load placed and the possible effects of hormones [7,34–36]. The present study did not identify BMI as a predictor of attrition in female light infantry soldiers, which might be explained by the narrow distribution of BMI values in the tested population, in which 47.3% of subjects were of normal weight, and less than 10% were either underweight or obese. The lack of a relationship between BMI and attrition in military recruits has previously been reported, and US Army data showed that the BMI of a recruit was not related to the rate of attrition during basic combat training [7,8,26,37,38]. Also, a study that measured the attrition among male and female soldiers found that enlistees who exceeded normal weight and amounts of body fat, but passed an endurance step-test and push-up test, did not have a significantly increased risk of attrition when compared with recruits with normal weight and body fat measurements [39].

In the present study, the attrition rate for newly recruited female light infantry soldiers from training to combat service was 31.7% at 18 months, which is similar to the previously reported attrition rate of 28% at 36 months in a comparable population [4]. However, other studies have reported lower rates, which might be due to the difference in populations tested [8,16,17]. It should also be noted that most attrition occurs in the early phase of military service [4].

The current study applied a modified version of the Ranger Test (RT), with an 8 kg backpack instead of the 20 kg backpack used by Larsson et al. [24]. The backpack weight was reduced due to the difference between the studied populations: male soldiers (mean height: 1.81±0.06 m; mean weight: 75.3±7.5 kg) compared with female soldiers (mean height: 1.61±0.06 m; mean weight: 61.8±10.2 kg), and was selected based on a pilot test with female soldiers, which identified the optimal weight to perform the test. A previously modified version of the Ranger Test that was also performed on female soldiers (median height: 1.60 m; median weight: 66.3 kg) used a 17 kg vest but reduced the bench height to 0.3 m [37]. However, in this previously published study, the soldiers were pre-deployment and past basic training, enabling a more strenuous test to be used [37].

The present study showed a weak correlation between the height of the subjects and the number of steps performed in the MRT (r=0.2). This finding was in contrast to the results of the study by Larsson et al., who showed a moderate correlation between the height of the subject and the MRT results (r=0.47) [24]. Although this previous finding may be a result of gender difference, it should be further tested in additional studies.

As previously reported, the UQYBT scores were found to be highly reliable and to be significantly correlated between each direction and side, as shown in Tables 2 and 3 [23,29]. These findings question the need to perform the entire test, which consists of 18 repetitions, as the additional directions and repetitions may not add value to the test.

This study had several limitations that should be considered when interpreting the findings. The study design was retrospective and the cohort consisted of a relatively small sample of female light infantry soldiers. Future prospective studies with more participants, including female soldiers from other military combat units, are warranted. Also, it is important to note that military service in the Israeli Defense Force is mandatory for both men and women. However, women are not obligated to serve in combat units, and the population of the current study volunteered for these duties. Other factors that can influence drop out rates, such as aerobic capacity, motivation, and mental resilience, were not controlled for in the present study. While physical factors may indicate motivation and resiliance during the time of measurement, they are not considered to be direct outcome measures for these factors. Future studies should be undertaken to validate the findings of the results of this study while controlling for other known risk factors for attrition rates for military recruits.

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Conclusions

Attrition, or dropout, of female soldiers between training and combat in the field, is of particular concern in the armed forces. The results of this study on women in the Israeli light infantry have shown that a simple screening procedure undertaken at the time of military training may be used to identify female soldiers who might be prone to attrition during combat. A modified version of the Ranger Test (MRT) included a lower limb step-up endurance test that predicted the attrition of female recruits with 73.7% sensitivity and 50.9% specificity. No predictive value was found for an upper limb stability test, the Upper Quarter Y-Balance Test (UQYBT), and body mass index (BMI). Further large-scale prospective studies should be undertaken to validate this finding and the predictive value of the MRT with a more heterogenous cohort of female combat soldiers. The results of this study should encourage further research on the use of functional musculoskeletal testing to predict attrition during combat in women in the military.

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Conflict of interest:

None.

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